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END-OF-MONTH CUMULATIVE EFFECTIVE RAINFALL IN ENGLAND

AGRICULTURAL MEMORANDUM 854

INTRODUCTION

Information on median and interquartile ranges of end-of-month cumulative Effective Rainfall (ER) is of interest to Soil Scientist and others concerned with advising farmers on the possible course of winter nitrate leaching etc.

In a preliminary report (Ag Mem 831) end-of-month cumulative 'ER' statistics were compiled for 6 stations in SE England using the Meteorological Office Short Rooted Vegetation 'Actual Evaporation' Program. The program is based on a soil water extraction model with a 76.2 mm 'Penman' root constant. Monthly 'Penman' evapotranspiration (PT) figures are calculated and daily values ascribed based on a smooth seasonal progression. These values of summer PT are over-estimated according to the latest analyses of Wales - Smith (1979). The effect on 'actual' soil moisture deficits will depend on the soil water extraction model used (see Appendix). This present Memorandum extends the ER analysis of Ag Mem 831 to 17 stations in England (range of Average Annual Rainfall, AAR, of 589 to 1044 mm); further work cannot be justified until the 'Effective Rainfall Program' incorporates, for example, more accurate estimates of daily PT and better soil extraction models (including soil type variations), factors which are currently being investigated by Met O8 (Wales - Smith 1976, 1979). Tabony (1979) does investigate quintiles of annual variations in ER and other parameters for different root constants using Smith's values of potential evapotranspiration.

METHOD

Using, generally, some 17 years of data (1961-77) generated by the Met Office 'Actual Evaporation' Program, tabulations were made of the end-of-month (October to April) cumulative 'ER' for 17 stations around England.

From graphical presentations the values of medians (M) and interquartile ranges (IQR) of 'ER' were deduced; maximum, minimum and average values were also noted (Table 1).

A Hewlett Packard 9810A 'Statistical Package' was applied to the data sets using an HP10 calculator; the results are listed in Table 2 for the following parameters.

$$\text{I} \quad Y = \frac{\text{Median ER (M)}}{\text{Av Annual Rainfall (AAR)}}, \quad X = \text{AAR}$$

$$\text{II} \quad Y = \frac{\text{Upper boundary of lower quartile } (P_{25})}{M}, \quad X = \frac{M}{AAR}$$

$$\text{III} \quad Y = \frac{\text{Lower boundary of upper quartile } (P_{75})}{M}, \quad X = \frac{M}{AAR}$$

(P_{25} is value of ER below which 25% of data lie

P_{75} " " " " " 75% " " "

$P_{75}-P_{25}$ represents the Interquartile Range of ER)

FH2B

Figures 1 and 2 display the best fit parabolae for these sets of parameters. The coefficients of determination, R^2, were generally above 0.75, implying that ERs display a systematic variation from east to west and that a good estimate of certainly the January and February values of the IQR of the 'ER' for a station may be deduced with knowledge of the AAR alone (as indicated on the January figures).

FURTHER WORK

A more detailed analysis (incorporating the improvements already mentioned in the Introduction) could investigate the end of month variation of ER with altitude, as a function of $\frac{\text{winter rainfall}}{\text{AAR}}$ % etc., and should extend to ER under cereals grown on different soil types.

ACKNOWLEDGEMENTS

Suggestions of Mr C K Folland Met 08 were most welcome.

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Tabony R C (1979) Quintiles of the dates of return to and loss of field capacity and of hydrologically effective precipitation over England and Wales Met Office. (Met 08) Hydrological Memorandum 42.

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W.M.O. (in press)

J R STARR
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July 1979

Any comments or suggestions on this paper should be referred to the author.

Appendix

Comparison at Kew observatory (1964-70) of:

a. Monthly PT (mm) calculated for short rooted vegetation from 'Penman' using Z/Zo = 100 (Z: height of wind measurement, 2 m; Zo 'roughness length' for grass taken as 0.02 m). As used in the 'Actual Evaporation Program'.

With:

b. Latest PT calculations for a 'typical lowland catchment under short grass' incorporating improvements by Monteith, Thom and Oliver and using Z/Zo = 400 as used in the Meteorological Office Rainfall and Evaporation Calculating System (MORECS)

	Jan	Feb	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
PT_{100}	9.6	19.3	42.2	59.2	91.6	109.4	103.7	82.7	50.3	25.5	12.0	7.5
PT_{400}	9.9	15.8	33.6	48.0	70.6	87.8	88.4	73.7	48.0	26.5	14.1	9.3
Av. Rainfall	44	35	43	56	52	52	63	64	55	45	64	58

Noticeably: $PT_{100} > PT_{400}$ February to August.

The actual smd will be dependant on the soil water extraction model used - the 'Actual Evaporation Program' uses a Penman, root constant of 76.2 mm, the actual smd increasing only fractionally after the potential smd has fallen below 125 mm. The MORECS model allows 80 mm (A) of water to be extracted at the potential rate (under short rooted vegetation); it permits a greater build-up of actual smd - to a maximum of $2\frac{1}{2}$ A.

MORECS type soil moisture calculations (using PT_{400}) would, therefore, give less summer potential transpiration but permit this 'demand' to extract more moisture at large smds.

The net effect is that 'effective rainfall' will be less than the corresponding MORECS value under a Penman potential smd $<$ 125 mm and greater when the Penman potential is $>$ 125 mm.

Cumulative Effective Rainfall - Grassland (data 1961-77)

Shinfield (AAR=640 mm); height:62 m, NGR:4729E 1684N

	Dec	Jan	Feb	March	April
Median	72	117	150	174	178
Average	76	124	152	176	182
Maximum	193	268	324	356	357
Season	76/77	74/75	76/77	76/77	76/77
Minimum	0	14	14	33	33
Season	64/65 73/74	64/65	64/65	64/65	64/65
IQR	117/23	162/77	201/98	222/128	222/140

Aylesbury (627), 96 m, 4841E 2115N

	Dec	Jan	Feb	March	April
Median	72	112	137	160	162
Average	68	110	135	156	161
Maximum	167	221	301	320	320
Season	76/77	76/77	76/77	76/77	76/77
Minimum	0	0	0	3	3
Season	64/65 69/70 73/74 75/76	64/65	64/65	64/65	64/65
IQR	110/17	162/62	188/80	202/108	207/113

Gatwick (771), 59 m, 5265E 1407N

	Dec	Jan	Feb	March	April
Median	134	192	230	255	278
Average	130	198	238	267	280
Maximum	274	383	442	485	487
Season	76/77	76/77	76/77	76/77	76/77
Minimum	2	88	97	105	105
Season	73/74	75/76	64/65	75/76	75/76
IQR	166/81	237/147	294/189	324/204	338/220

Benson (AAR=607mm), height: 67 m, NCR: 4633E 1909N

	Dec	Jan	Feb	March	April
Median	53	99	132	151	153
Average	59	101	130	149	152
Maximum	156	212	233	272	276
Season	66/67	74/75	66/67	74/75	74/75
Minimum	0	0	0	0	0
Season	64/65 69/70 71/72 73/74 75/76	75/76	75/76	75/76	75/76
IQR	98/0	146/58	174/77	190/107	194/109

Hurn (806), 10 m, 4117E 0978N

	Dec	Jan	Feb	March	April
Median	144	244	264	301	312
Average	144	225	273	309	314
Maximum	341	432	549	600	600
Season	76/77	76/77	76/77	76/77	76/77
Minimum	0	54	68	80	80
Season	71/72	75/76	75/76	75/76	75/76
IQR	198/92	294/177	330/208	385/223	385/244

Wye (739), 56 m, 6057E 1469N

	Dec	Jan	Feb	March	April
Median	105	156	196	205	233
Average	122	174	210	237	247
Maximum	327	389	451	491	493
Season	66/67	76/77	76/77	76/77	74/75
Minimum	0	36	66	68	68
Season	71/72	72/73	72/73	72/73	72/73
IQR	145/72	197/110	266/133	280/150	278/172

Martyr Worthy (AAR=809mm), height: 84 m, NGR: 4517E 1338N

	Dec	Jan	Feb	March	April
Median	140	212	268	288	303
Average	147	227	274	312	320
Maximum	310	418	507	567	567
Season	76/77	74/75	76/77	76/77	76/77
Minimum	21	75	94	100	100
Season	73/74	75/76	64/65	75/76	75/76
IQR	185/97	268/158	337/210	365/238	380/250

Filton (783), 59 m, 3600E 1805N

	Dec	Jan	Feb	March	April
Median	115	183	214	239	248
Average	120	183	226	250	257
Maximum	280	322	438	462	462
Season	65/66	76/77	76/77	76/77	76/77
Minimum	0	22	40	67	67
Season	73/74	75/76	75/76	75/76	75/76
IQR	175/64	237/125	286/149	315/178	318/188

Rosewarne (1044), 76 m, 1643E 0412N

	Dec	Jan	Feb	March	April
Median	278	404	479	554	559
Average	275	400	489	550	568
Maximum	431	533	722	745	849
Season	65/66	76/77	65/66	65/66	65/66
Minimum	96	245	292	369	369
Season	71/72	71/72	64/65	64/65	64/65
IQR	329/222	465/334	557/415	620/480	634/485

Plymouth (971), 36 m, 2478E 0537N

	Dec	Jan	Feb	March	April
Median	198	306	373	425	457
Average	206	307	382	435	451
Maximum	445	553	695	714	806
Season	65/66	65/66	65/66	65/66	65/66
Minimum	44	65	109	189	189
Season	75/76	75/76	75/76	75/76	75/76
IQR	260/137	361/232	440/309	482/375	505/388

Boscombe Down (AAR=724mm), height: 126 m, NGR 4172E 1403N

	Dec	Jan	Feb	March	April
Median	102	175	213	241	250
Average	103	175	213	244	248
Maximum	299	366	477	521	521
Season	76/77	76/77	76/77	76/77	76/77
Minimum	0	0	11	19	19
Season	71/72 73/74 75/76	75/76	75/76	75/76	75/76
IQR	150/56	217/130	267/146	288/185	295/198

Elmdon (679), 96 m, 4176E 2839N

	Dec	Jan	Feb	March	April
Median	46	100	130	157	166
Average	60	107	143	167	173
Maximum	174	219	345	362	362
Season	65/66	76/77	76/77	76/77	76/77
Minimum	0	0	0	0	0
Season	64/65 73/74 75/76	75/76	75/76	75/76	75/76
IQR	83/18	137/70	184/85	207/113	208/118

Watnall (716), 117 m, 4503E 3456N

	Dec	Jan	Feb	March	April
Median	142	218	267	293	312
Average	146	228	278	311	322
Maximum	319	446	479	527	527
Season	68/69	68/69	68/69	68/69	68/69
Minimum	18	109	110	117	117
Season	73/74	75/76	64/65	75/76	75/76
IQR	177/103	270/175	329/217	364/251	385/260

Honnington (AAR=589mm), height: 149 m, NGR: 5887E 2749N

	Dec	Jan	Feb	March	April
Median	-	61	80	88	91
Average	32	61	80	91	95
Maximum	85	140	183	186	194
Season	66/67	70/71	76/77	76/77	74/75
Minimum	0	0	0	0	0
Season	63/64 64/65 69/70 72/73 73/74 75/76	72/73	72/73	72/73	72/73
IQR	-	87/33	113/44	117/58	128/57

Carlisle (871), 26 m, 3384E 5603N

	Dec	Jan	Feb	March	April
Median	175	245	266	290	303
Average	184	249	283	284	324
Maximum	336	392	423	490	490
Season	67/68	67/68	67/68	67/68	67/68
Minimum	37	89	115	129	129
Season	72/73	72/73	72/73	72/73	72/73
IQR	225/137	293/200	328/215	353/243	354/268

Cockle Park (729), 99 m, 4200E 5912N

	Dec	Jan	Feb	March	April
Median	105	178	208	236	262
Average	127	182	222	249	262
Maximum	397	434	550	550	582
Season	65/66	65/66	65/66	65/66	65/66
Minimum	0	0	0	0	0
Season	72/73	72/73	72/73	72/73	72/73
IQR	167/60	232/124	280/130	300/160	325/188

Leeming (AAR=611mm), height:32 m, NGR:4306E 4890N

	Dec	Jan	Feb	March	April
Median	-	68	97	116	122
Average	-	84	113	130	135
Maximum	-	269	343	363	363
Season	-	76/77	76/77	76/77	76/77
Minimum	0	0	0	7	7
Season	62/63 64/65 70/71 71/72 72/73 75/76	62/63 64/65 72/73	64/65	72/73	72/73
IQR	-	110/33	147/50	165/68	180/74

TABLE 2

I: $Y = \frac{M}{ARR}$; $X = AAR$

	LINEAR $Y=A+BX$			PARABOLIC $Y=A+BX+CX^2$				EXPONENTIAL $Y=Ae^{BX}$			POWER $Y=AX^B$		
	A	$Bx10^{-2}$	R^2	A	B	$Cx10^{-5}$	R^2	A	$Bx10^{-3}$	R^2	$Ax10^{-4}$	B	R^2
January	-17.546	5.44	0.829	-49.434	0.137	-5.2	0.846	3.537	2.44	0.751	0.6	1.938	0.7933
February	-14.438	5.68	0.790	-39.158	0.121	-4.0	0.799	5.727	2.07	0.731	5.3	1.640	0.7688
March	-15.567	6.31	0.793	-22.907	0.082	-1.2	0.794	6.875	1.99	0.742	9.7	1.568	0.7771
April	-17.069	6.75	0.789	-49.386	0.151	-5.3	0.800	6.794	2.07	0.733	6.1	1.646	0.7784

II: $Y = \frac{P_{25}}{M}$; $X = \frac{M}{ARR}$

	A	B	R^2	A	B	C	R^2	A	$Bx10^{-2}$	R^2	A	B	R^2
J	43.232	1.138	0.767	28.560	2.519	-2.92	0.806	46.282	1.71	0.740	21.434	0.378	0.797
F	36.558	1.203	0.817	27.160	1.906	-1.22	0.826	42.628	1.74	0.807	15.119	0.463	0.819
M	51.564	0.759	0.721	42.037	1.368	-0.90	0.736	54.621	1.00	0.705	25.796	0.313	0.720
A	54.326	0.667	0.720	39.21	1.619	-1.38	0.765	56.534	0.89	0.714	27.730	0.292	0.771

III: $Y = \frac{P_{75}}{M}$; $X = \frac{M}{ARR}$

	A	B	R^2	A	B	$Cx10^{-2}$	R^2	A	$Bx10^{-2}$	R^2	A	B	R^2
J	166.315	-1.556	0.774	187.726	-3.571	4.26	0.818	170.309	-1.18	0.780	284.005	-0.254	0.803
F	159.642	-1.023	0.823	167.362	-1.601	0.99	0.831	162.625	-0.78	0.837	256.247	-0.205	0.822
M	147.831	-0.665	0.645	143.089	-0.036	0.45	0.650	149.85	-0.53	0.655	216.504	-0.157	0.603
A	149.706	-0.751	0.647	170.302	-2.049	1.89	0.707	151.489	-0.59	0.662	242.383	-0.193	0.712

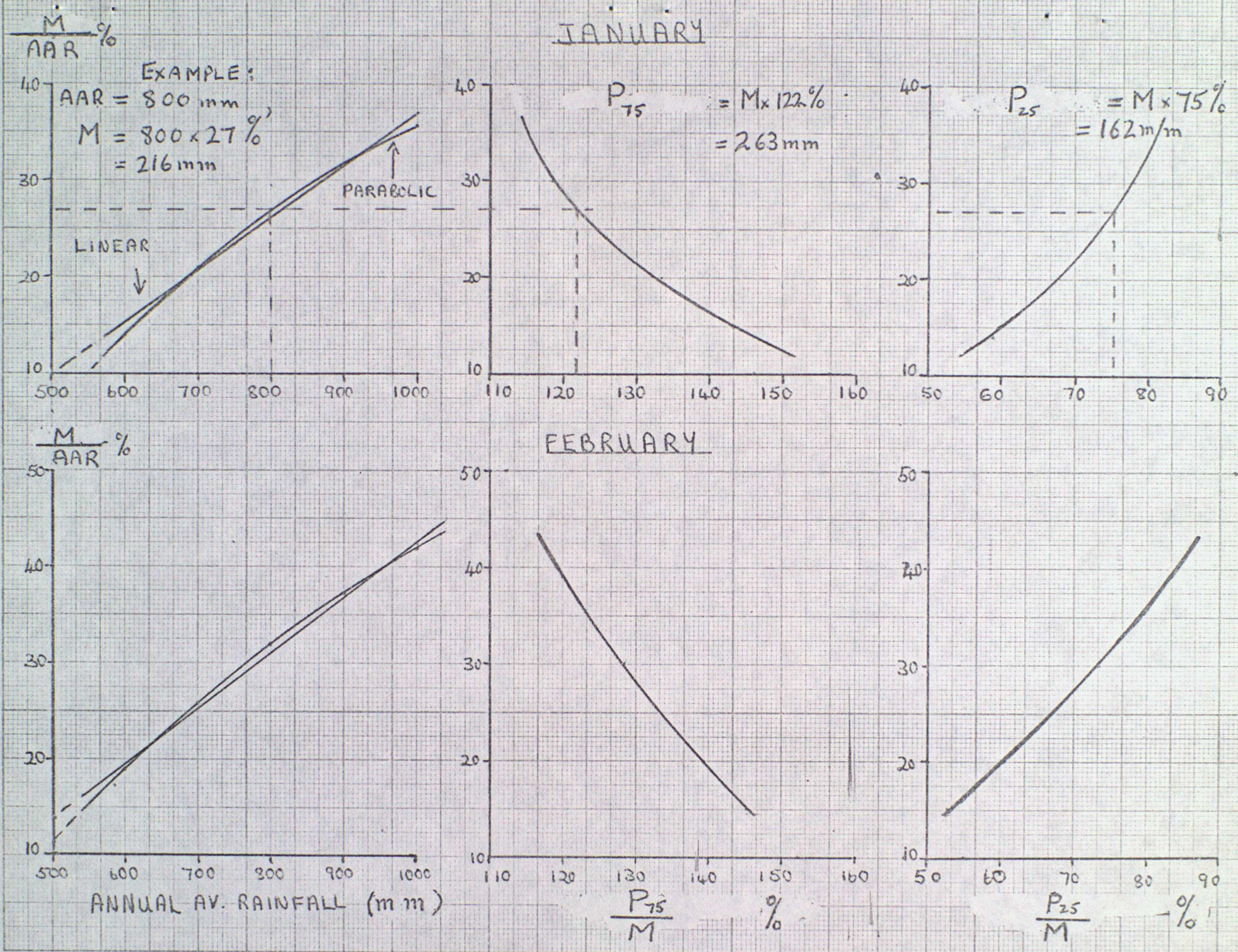
JANUARY
FEBRUARY
M/AAR %
EXAMPLE:
AAR = 800 mm
M = 800 × 27 %
= 216 mm
LINEAR
PARABOLIC
P_{75} = M × 122 %
= 263 mm
P_{25} = M × 75 %
= 162 mm
40
30
20
10
50
500 600 700 800 900 1000
110 120 130 140 150 160
50 60 70 80 90
ANNUAL AV. RAINFALL (mm)
$\frac{P_{75}}{M}$ %
$\frac{P_{25}}{M}$ %

Fig. 1

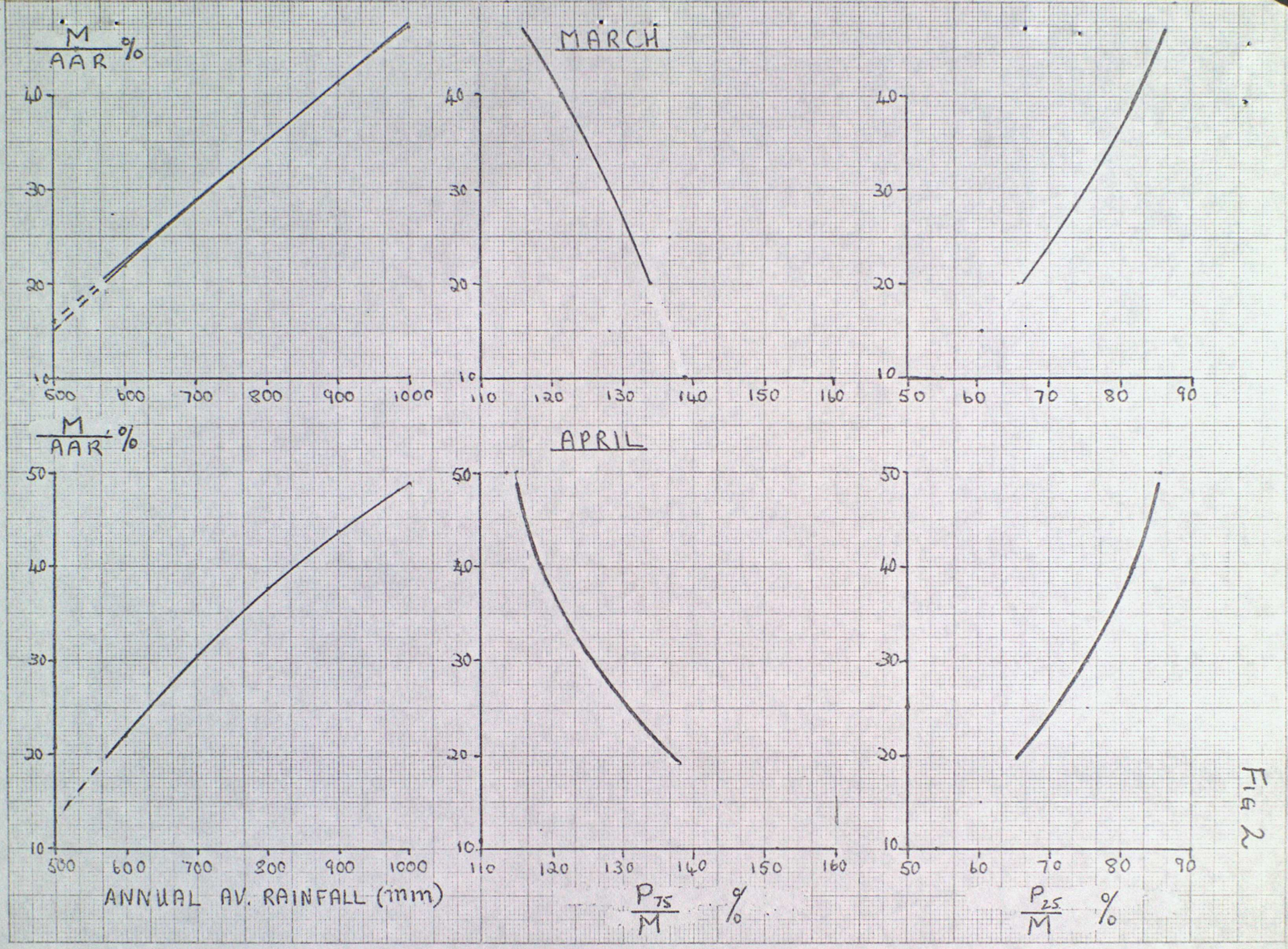
MARCH
APRIL
M/AAR %
40
30
20
10
600
700
800
900
1000
110
120
130
140
150
160
50
60
70
80
90
ANNUAL AV. RAINFALL (mm)
P75/M %
P25/M %

FIG 2